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HURRICANE RETURN PERIODS

ALONG THE GULF COAST AND FLORIDA

J. B. Elsner
A. B. Kara

Cooperative Institute for Tropical Meteorology
Department of Meteorology
Florida State University

Scientific Services Division
Southern Region
Fort Worth, TX

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William M. Daley, Secretary

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James Baker
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National Weather Service
Robert Winokur
Acting Assistant Administrator

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Introduction

Though quite rare at any particular location, hurricanes are natural disasters because of their negative impact on society. Return periods are used to estimate the likelihood of rare events that are not periodic in time. The qualification of aperiodic is important. A phenomenon that occurs on a regular basis is best described in terms of periods or frequencies. Return periods on the other hand are appropriately used when there is not a dominant period of oscillation. A return period is typically defined as the average time between successive events. For a particular phenomenon the time between events may vary considerably, but the average of all times is the return period. Thus, a return period of ten years is correctly interpreted as an average of ten years between events and should not be understood as a forecast of an event happening about every ten years—although it is commonly misinterpreted in exactly that way. Here we examine return period statistics for U.S. coastal counties along the Gulf of Mexico and Florida.

Return Periods and Wait Times

From the total number of landfalls L for a given coastal region (such as a state or county) over a period of record of length N, the average annual probability of a strike can be computed as the ratio

$$P = L/N.$$

A coast that has been struck ten times in 100 years has an annual probability of 0.10 (or 10%). The return period RP, which indicates the average number of years between landfalls, is given as the inverse of the average annual probability

$$RP = 1/P.$$

Thus the return period for an annual probability of 0.10 is 10 years. It is often of interest to compute the wait time (W) in years within which there exists a better than 50 percent chance of at least one landfall. This is done using

$$(1-P)^W \geq 0.50,$$

where P is the annual landfall probability. Wait time is the number of consecutive years over which the probability of observing at least one hurricane becomes greater than 50% in the successive year interval. For the example above, a wait time (W) of between six and seven years will give a probability of better than 50% of observing at least one landfall. That is, you can expect to wait an average of six to seven years before your probability of getting hit anytime in the interval equals that of flipping a fair coin. Your probability of getting hit in any particular year, of course, remains constant and fairly low. (Recall we are assuming in this example that landfalls during the period N are aperiodic —that is, equally likely in any given year.)

Coastal Counties

Here we present return period statistics for individual coastal counties along the Gulf of Mexico and in Florida based on the hurricane chronology of Jarrell, et al. (1992). Their work stratifies hurricanes for each coastal county according to direct and indirect strikes. The radius of maximum winds (R) is defined as the distance from the hurricane center to the circle of maximum winds around the center. A county is regarded as getting a direct hit when all or parts of the county fall within $2R$ to the right and R to the left of a storm's landfall with respect to the direction of motion (that is, from the perspective of someone at sea looking toward the shoreline). On average the direct hit zone extends roughly 80 km (50 mi) along the coastline (R is approximately 24 km). Some hurricanes may be smaller or larger and each storm was judged by Jarrell, et al. (1992) individually. An indirect hit generally occurs on either side of the direct hit zone where winds still exceed hurricane force or where tides are at least four to five feet above normal. Again, much subjectivity was necessary in making these decisions.

Hits to coastal counties are counted for storms that retain their hurricane intensity as they move from land to sea as is sometimes the case in Florida and elsewhere. The chronological lists of Jarrell, et al. (1992) extend from 1900 to 1990. Here we update this chronology to include hurricane landfalls through 1996. There were seven U.S. hurricane strikes in the period 1991--1996 including Bob in 1991, Andrew in 1992, Emily in 1992, Erin and Opal in 1995, and Bertha and Fran in 1996. The inclusion of counties affected by these storms for the present work is based on post-hurricane analyses made by various forecasters at the National Hurricane Center.

Return period statistics (average return periods and wait times) for hurricane strikes (direct plus indirect) are given for all U.S. counties along the Gulf of Mexico and in Florida by region. (The analysis is done for the entire U.S. coast in Elsner and Kara [1998], and that publication contains numerous other Atlantic hurricane statistics as well.) A coastal county receiving a direct or indirect hurricane strike can be considered one in which hurricane force winds (>33 ms^{-1}) occurred somewhere in the county. The numbers on the figures are rounded to the nearest year for return periods and wait times. Overall the ratio of the number of accounts of major hurricane force winds to the number of accounts of any hurricane winds is approximately 25%. That is, about one-quarter of all counties experiencing hurricane force winds were hit by winds in excess of 50 ms^{-1} (110 mph).

Figure 1 gives the names of the coastal counties in Texas with the average hurricane return periods and average wait times in years. Return periods range from a high of 14 years for Cameron County to a low of five years for Galveston County (which includes the city of Galveston). In general, return periods and wait times are slightly lower for the central and northern Texas coastline, though the difference with the south Texas coast is only marginal. Eight of the 17 counties have wait times of less than five years. The estimates of hurricane return periods are similar to those given in Simpson and Lawrence (1971). Based on data from 1886-1970 they divided the Gulf and Atlantic coast into 58 50-mile segments and estimated tropical storm and hurricane frequencies for each segment.

Return periods and wait times for hurricanes affecting the parishes of Louisiana from 1900--1996 are given in Fig. 2. Hurricane force winds have a mean return period of between eight and 20 years with Terrebonne and Plaquemines the most frequently affected parishes. (Plaquemines Parish was hit in July 1997 by hurricane Danny.) Orleans Parish (New Orleans) has a wait time of approximately ten years. Though the return periods for Louisiana parishes are typically a few years longer than return periods of Texas counties, the return periods for major hurricanes are a bit shorter than they are for Texas counties (see Elsner and Kara 1998). The five counties of Mississippi and Alabama are shown in Fig. 3. The average return period ranges between eight and 12 years. Harrison and Jackson Counties in Mississippi have the shortest wait times, approximately five years.

The counties in Florida show a wide range of return periods, as seen in Fig. 4. Counties along the Panhandle have average return periods close to ten years, but the counties of the northwest peninsula have return periods between 20 and 50 years. Wait times are shortest for Escambia (Pensacola) and Bay (Panama City) Counties and longest for Jefferson and Taylor Counties. Bay, Gulf and Franklin Counties are unusual in that hurricane frequencies are quite high, yet the frequencies of major hurricanes are low. Along the southwestern coast of Florida return periods generally range between 8 and 16 years. Hillsborough County, for example, which includes Tampa Bay, has a wait time of approximately eight years. The exception is Monroe County, which includes the Florida Keys and the city of Key West. Because the Keys extend westward into the Gulf of Mexico, Monroe County experiences the greatest frequency of direct hurricane landfalls of any U.S. county, with a return period of only four years and a wait time of just two years.

Along the southeast Florida coastline facing the Atlantic Ocean, hurricane frequencies are somewhat higher compared with along the Florida Gulf coast. In fact, overall, the southeast Atlantic coastal counties of Florida have the shortest average return period of anywhere in the United States. Dade County (Miami) rivals its neighbor to the west and south with a mean return period of only five years. Wait times generally increase going north with Indian River County having a wait time of six years. The trend toward longer hurricane return periods continues northward into the northeastern counties of coastal Florida. Return periods range from ten years in Brevard County (Melbourne) to 32 years in Nassau County on the Georgia border (see Fig. 4). It is of interest to note that no major hurricanes have hit northeastern Florida (FL_{ne}) this century.

The return periods for Florida are slightly different than those in Ho, et al. (1987) who showed higher frequencies of landfalling tropical cyclones along the Gulf coast, compared to the Atlantic coast. This is likely due to the fact that they are considered both tropical storms and hurricanes in their analysis. We note the largest differences in frequencies going from all hurricanes to major hurricanes (not shown) occur along the Florida Gulf coast, in particular, the Big Bend region. This is consistent with Ho, et al. (1987) and suggests, in general, that the Florida Gulf Coast is more vulnerable to weaker tropical cyclones, while the Atlantic Coast is more threatened by the strongest hurricanes.

Limitations

The estimation of return periods above is accurate only under the following two assumptions: a) that each year has the same probability of a landfall, and b) that each landfall is an independent event. The assumption of constant probability can be examined with the aid of cumulative distributions such as those shown in Fig. 5. Compare, for instance, the cumulative distributions for northwestern and southeastern Florida. For northwestern Florida (FL_{nw}), the distribution suggests a relatively constant annual probability (at least over the last 100 years) whereas for southeastern Florida (FL_{se}) the annual probability changes with active and break periods (the flat steps in the graph) lasting a decade or more. This is not surprising since it has been shown that Atlantic hurricane frequencies are modulated by El Niño and the QBO (Gray 1984). In particular, hurricane strike probabilities for the U.S. are related to the phases of ENSO (O'Brien, et al. 1996).

The most pronounced active period (looking at FL_{se}) occurred from the middle 1920s through the middle 1940s. The period from the middle 1960s through the 1980s was a prolonged break period punctuated by very few strikes. The active and break regimes make it misleading to assign a single constant hit rate for the entire 1900-1996 period. It also suggests that the frequencies and return periods of south Florida hurricanes are more sensitive to changes in climate than the frequency of hurricanes in north Florida, which might be related to the relative abundance of landfalls from tropical-only versus baroclinically-enhanced hurricanes (Elsner, et al. 1996) to these two regions.

The assumption of independence can also be tested. Consider the occurrence of hurricanes in Florida. The total number of Florida landfalls over the period 1851 - 1996 is 91 (Elsner and Kara 1998), so the average annual probability is 62%. However, over the 146-year period there have been only 63 different years with hurricane strikes, making the probability of at least one Florida hurricane strike 43% (63/146). This clustering of strikes suggests that multiple hit years are more common than expected under the assumption of independent events. To continue, given that Florida gets hit with a hurricane in a particular year, there is 41% (26/63) chance of it getting hit again in the same year. The return period depends on what annual hit rate is used. If the average annual probability is used, then the return period is 1.6 years, but if the annual probability is estimated from the percentage of years with hits, then the return period is 2.3 years. Multiple hit years are also relatively common for North Carolina (see Elsner and Kara 1998).

Acknowledgments

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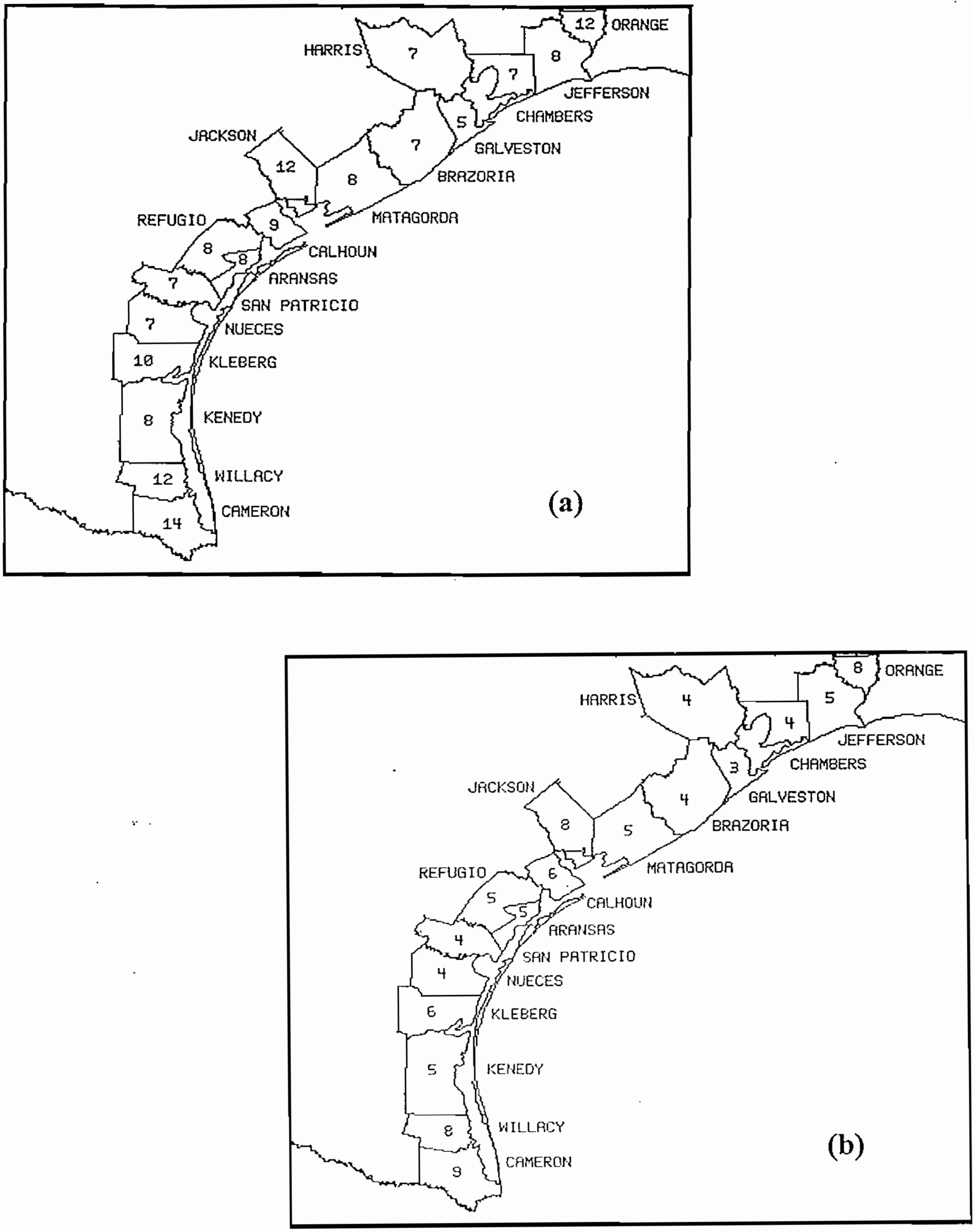


Fig. 1 Hurricane return periods (a) and wait times (b) for coastal counties in Texas, based on data from 1900-1996.

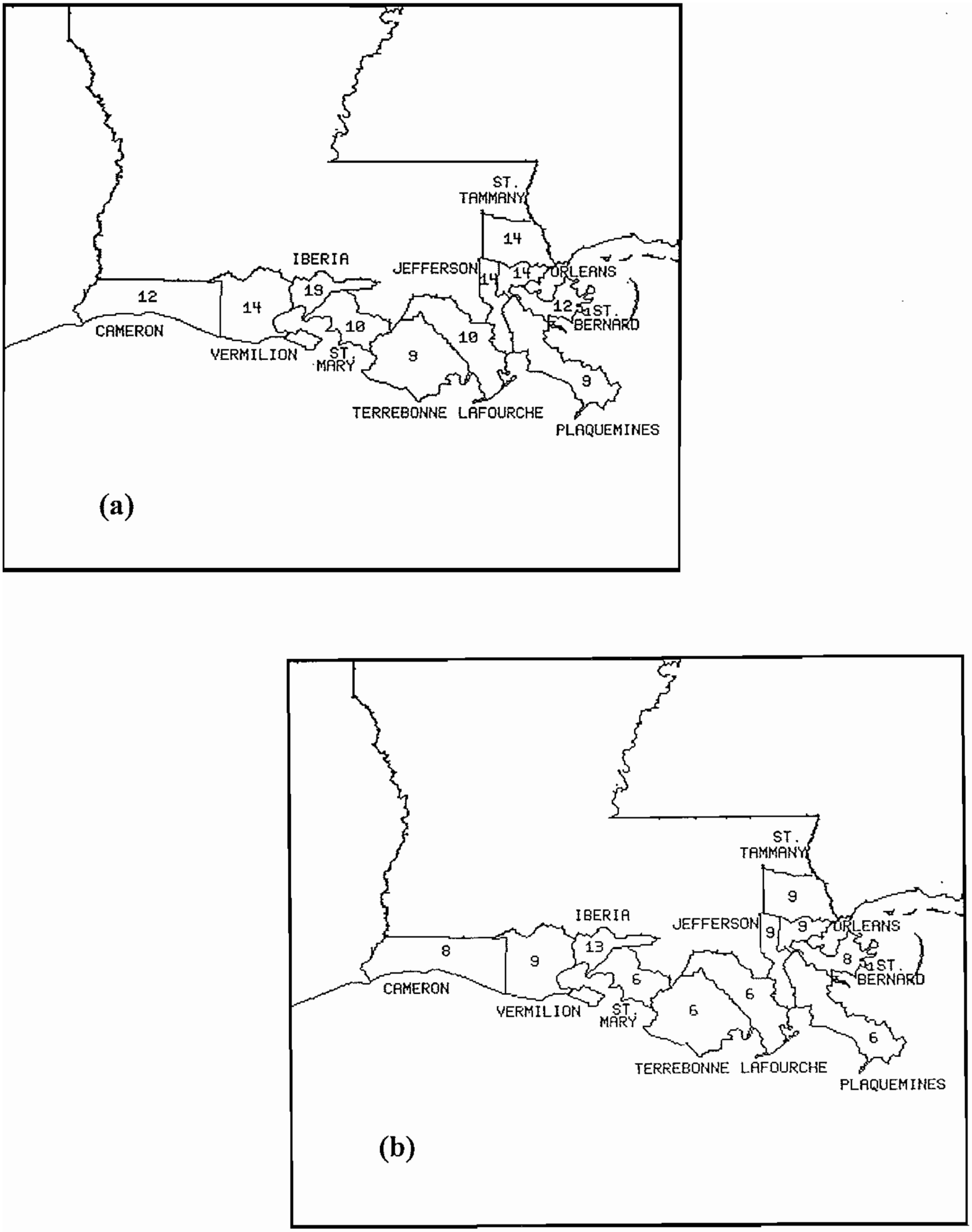
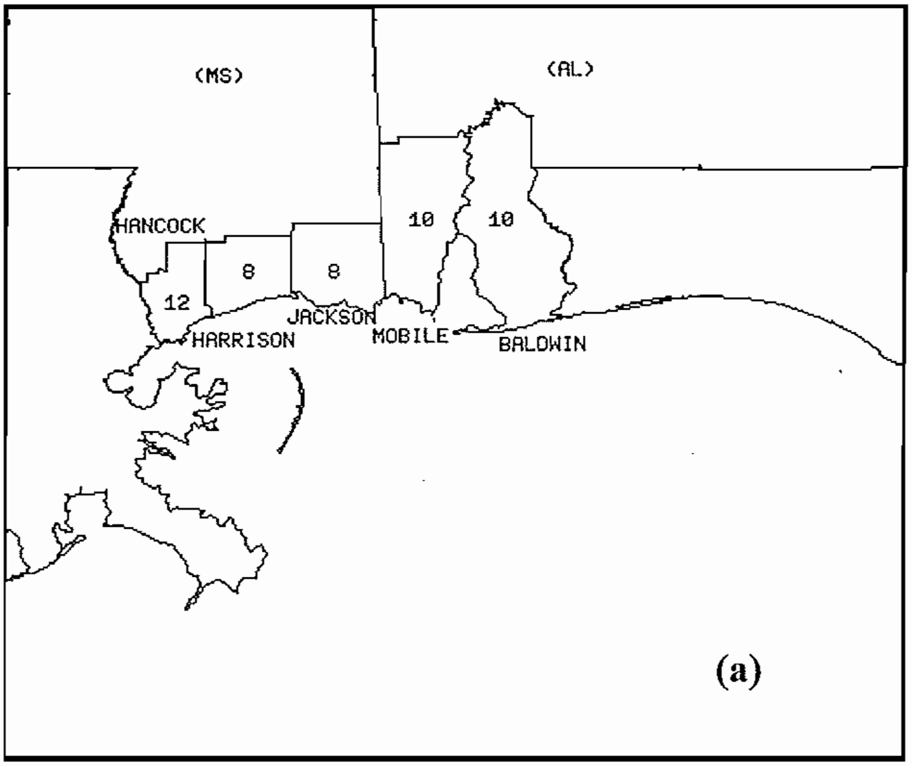


Fig. 2 Hurricane return periods (a) and wait times (b) for coastal parishes in Louisiana, based on data from 1900-1996.



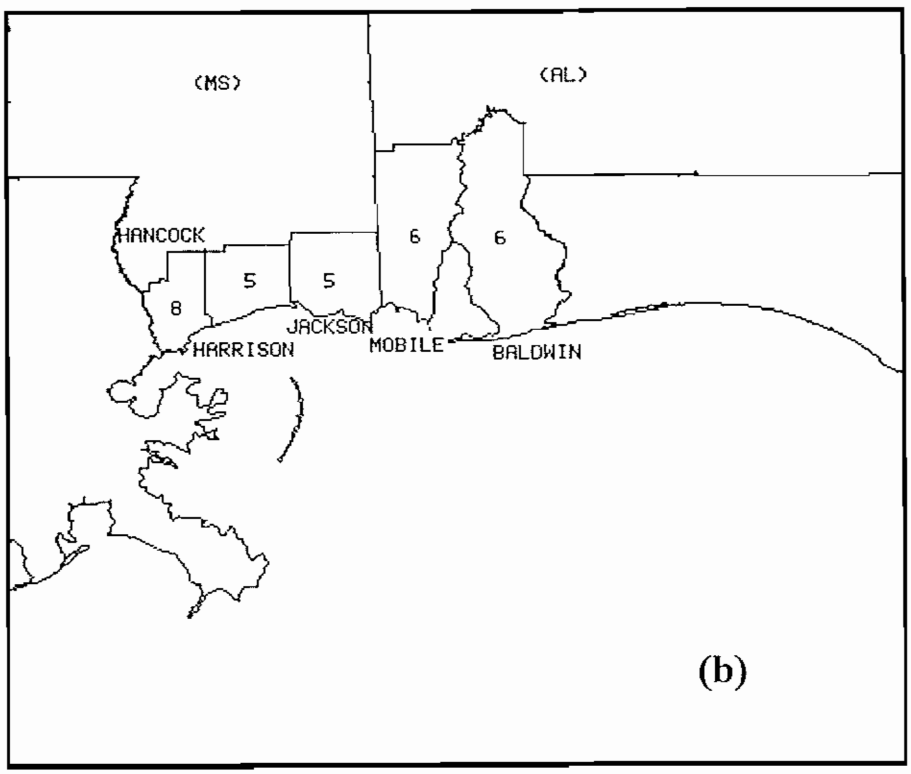
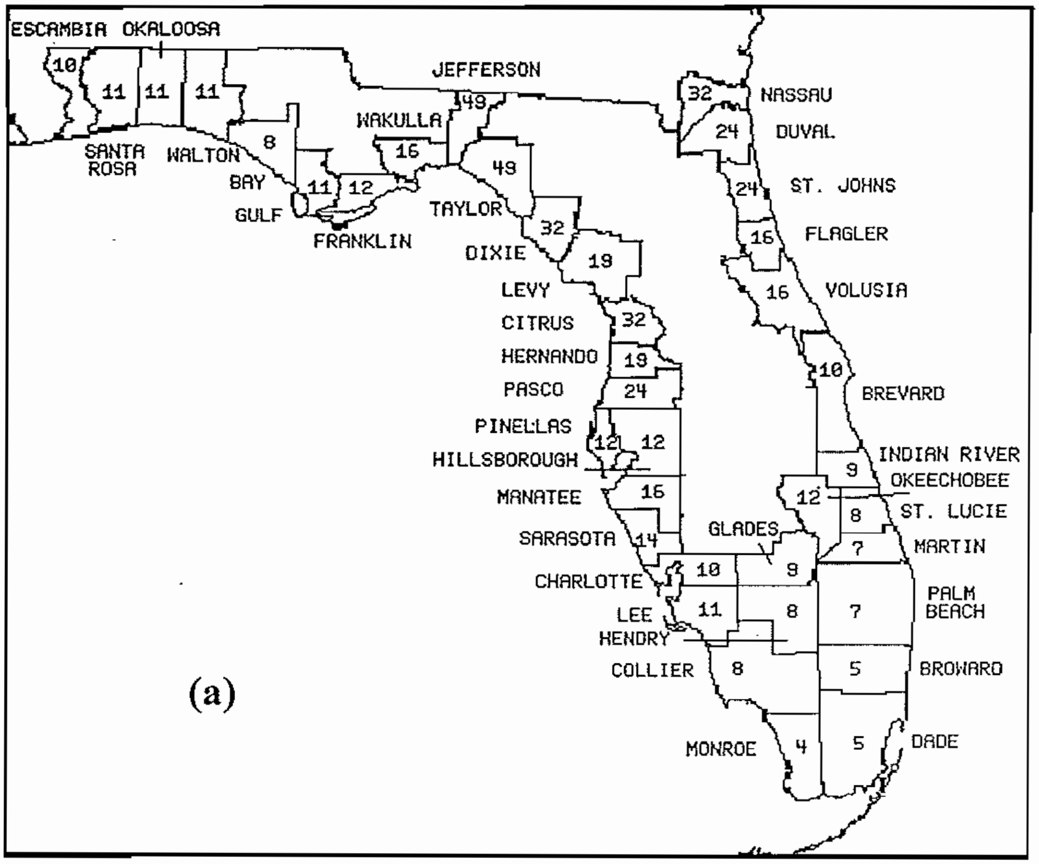


Fig. 3 Hurricane return periods (a) and wait times (b) for coastal counties in Mississippi and Alabama, based on data from 1900-1996.



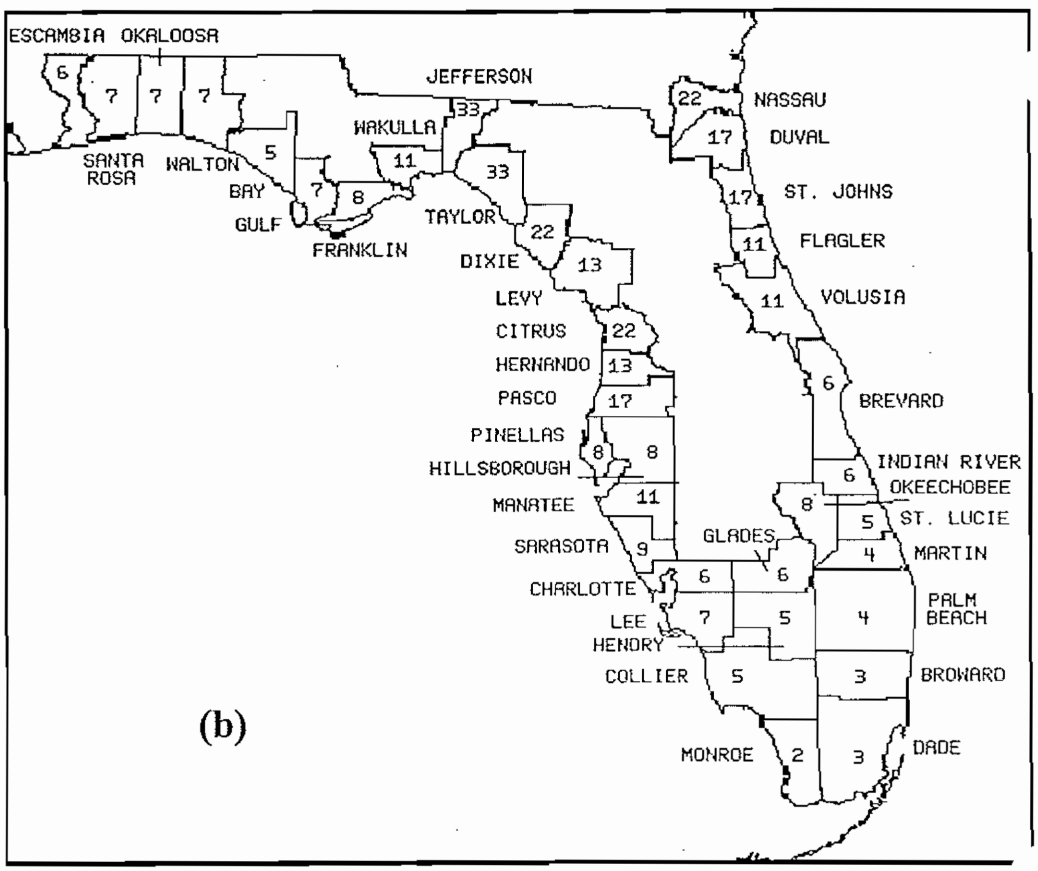


Fig. 4 Hurricane return periods (a) and wait times (b) for coastal counties in Florida, based on data from 1900-1996.

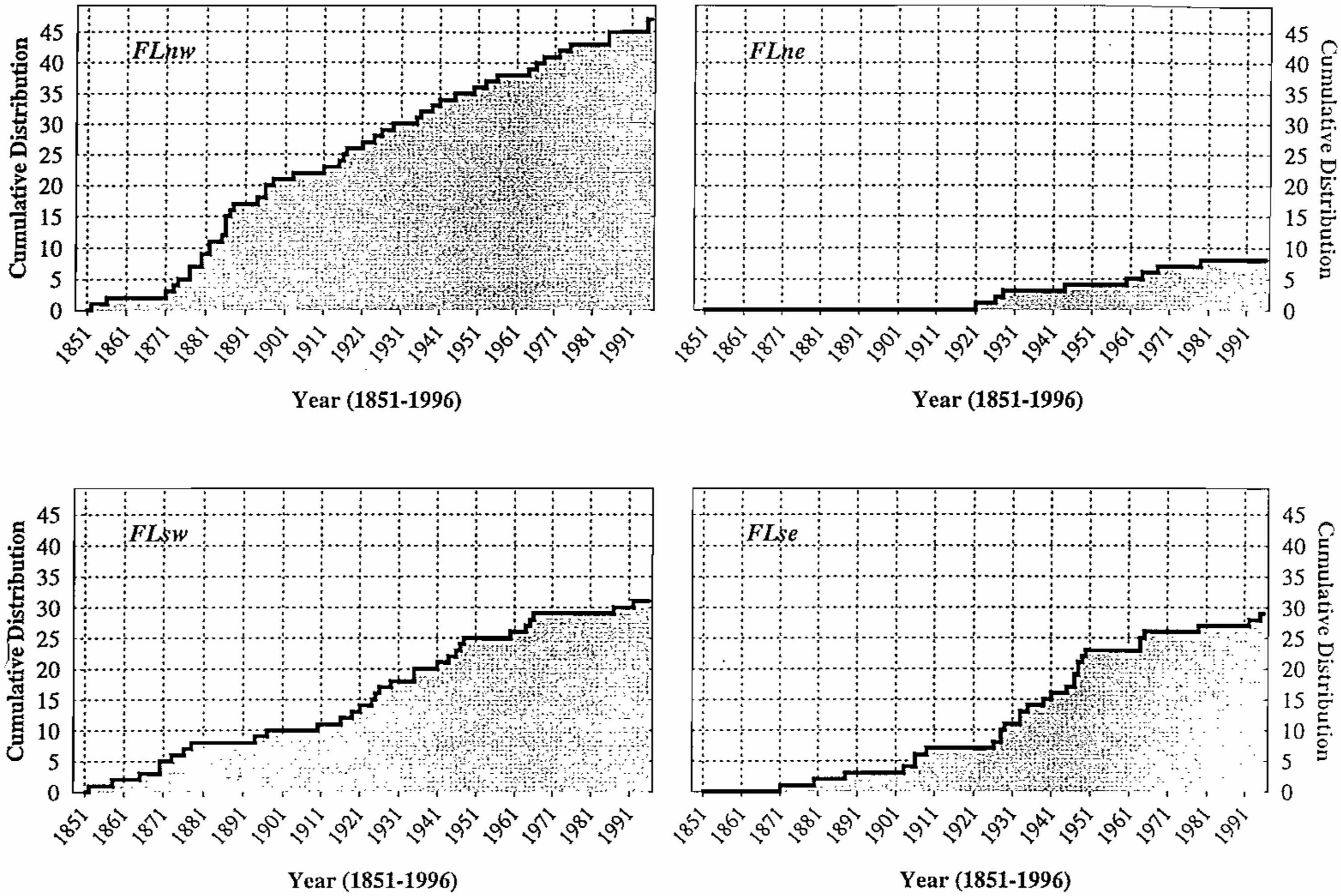


Fig. 5 Cumulative frequency of hurricane landfalls in Florida by region, based on data from 1851-1996 (Elsner and Kara 1998). Northwest Florida (FL_{nw}) extends from Escambia County through Pasco County, southwest Florida (FL_{sw}) from Pinellas County to Monroe County, southeast Florida (FL_{se}) from Dade County to Brevard County and northeast Florida (FL_{ne}) from Volusia County to Nassau County. See Fig. 4 for county locations.